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Influence of different adhesive systems and resin cements on their bond strength to root canal dentin: an integrative review

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Dissertação conducente ao Grau de Mestre em Medicina Dentária (Ciclo Integrado)

Gandra, 16 de Setembro de 2021

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Trabalho realizado sob a Orientação do Dr. Valter Fernandes e Professor Doutor Julio Souza

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AGRADECIMENTOS

First of all I would like to thank my family: my father, my mother, my sister Feryelle and my brother Marouane. I would not be here without you and your continuous support.

I would also like to thank those I now consider as my second family: to my "binôme" Rayhane, thank you for having supported me for 4 years for work and as a roommate; to Laurent, my first meeting when I arrived in Gandra, destiny always does things well; to Moustansir, even if you owe me a lot of time with your lateness "merci pour les travaux"; to the duo of the North House, Samuel my mentor (and his spirtual son Ilan) and Greg, I cherish every moment I spend in your company.

To Yassou, Amine, Amin and all the other brothers who have passed through Gandra, words would not be enough but I will only say that sometimes it only takes one meeting to change a life.

A very sincere collective thank you to all the people I have met during these 5 years, I can't name everyone for obvious reasons of space but you are all special and important to me.

Thank you to my "orientador" Dr. Valter Fernandes and my "co-orientador" Professor Dr. Julio Souza for your patience and your support that allowed me to complete this work. I would also like to thank all the teaching staff of the CESPU, especially the clinical teachers, as well as the staff of the CESPU as a whole.

RESUMO

Os espigões de fibra de vidro são amplamente utilizados na restauração de dentes tratados endodonticamente que apresentam uma extensa perda de estrutura coronal. Para sua adesão ao interior do canal radicular, são usados diferentes tipos de agentes cimentação. Os cimentos mais usados actualmente, os cimentos resinosos, podem ser divididos por três categorias principais: etch&rinse, self-etch and self-adhesives cements.

O objetivo deste trabalho é avaliar a influência de diferentes adesivos e cimentos de resina na sua força de ligação à dentina do canal radicular. Foi realizada uma pesquisa no PubMed em Janeiro de 2021, utilizando a seguinte combinação de termos de pesquisa:" Self-Etch Adhesive" OR "Self-Adhesive Cement" OR Self Etch Adhesive" OR "separate etch" OR "separate adhesive" OR "intraradicular bonding" AND "fiber post" OR "post" AND "bond strength" OR "dental bonding" OR "cement" AND "root canal" OR "dual cure cement" OR "adhesive". Um total de 196 artigos foram identificados no PubMed e 27 estudos foram incluídos nesta revisão sistemática integrativa tendo sido seleccionados de acordo com os critérios de inclusão e exclusão. Os resultados encontrados indicam que o self-etch é actualmente a melhor alternativa em termos de adesivos, porque apresentam resultados melhores ou iguais em termos push-out bond strength quando comparado com o etch-and-rinse (24,33MPa contra 18,61 MPa), para além da sua facilidade de utilização e de serem menos sensíveis à técnica. Os self-adhesive cements são também uma alternativa eficaz de acordo com a maioria dos autores, mostrando resultados de força de ligação igual ou melhor do que o etch-and-rinse ou o self-etch (22,17 ± 2,83 MPa para o SAC contra 11,13 ± 2,40 MPa para o E&R; 573,65 ± 71,66 N para o SAC contra 457,46 ±115,35 N para o SE). Além disso, tal como para o self-etch, são muito fáceis de utilizar, requerem menos tempo e são menos sensíveis à técnica. Contudo, pode ser necessário acrescentar alguns passos, tais como o etching ao utilizar self-etch ou self-adhesove para ultrapassar as suas limitações. Em condições óptimas, self-etch adesivos e self-adhesive cimentos fornecem resultados superiores de ligação dentina a etch&rinse adesivos e cimentos convencionais.

Palavras-chave: Self-Etch Adhesive, Self-Adhesive Cement, Fiber Post, Root canal, Bond strength

ABSTRACT

Glass fiber posts are a widely used in the restoration of endodontically treated teeth with extensive loss of coronal structure. For their adhesion to the interior of the root canal, different types of luting agents are used. Acutally, the most commonly used resin cements, can be divided into three main categories: etch&rinse, self-etch and self-adhesives cements.

The objective of this study is to evaluate the influence of different adhesives and resin cements on their bond strength to root canal dentin. A PubMed search was performed in January 2021 using the following combination of keywords: "Self-Etch Adhesive" OR "Self-Adhesive Cement" OR "Self Etch Adhesive" OR "separate etch" OR "separate adhesive" OR "intraradicular bonding" AND "fiber post" OR "post" AND "bond strength" OR "dental bonding" OR "cement" AND "root canal" OR "dual-cure cement" OR "adhesive". A total of 196 articles were identified in PubMed and 27 studies were included in this integrative systematic review and were selected according to the inclusion and exclusion criteria. The results found indicate that self-etch is currently the best alternative in terms of adhesives because they show better or equal push out bond strength results when compared to etch-and-rinse (24.33MPa against 18.61 MPa) in addition to their ease of use and being less sensitive to technique. Self-adhesive cements are also an effective alternative according to most authors, showing equal or better push out bond strength results than etch-and-rinse or self-etch (22.17 ± 2.83 MPa for the SAC against 11.13 ± 2.40 MPa for the E&R; 573.65 ± 71.66 N for the SAC against 457.46 ±115.35 N for the SE). Moreover, as for self-etch, they are very easy to use, require less time and are less sensitive to the technique. However, it may be necessary to add some steps such as etching when using self-etch or self-adhesive to overcome their limitations.

Under optimal conditions, self-etch adhesives and self-adhesive cements provide superior dentin bonding results to etch&rinse adhesives and conventional cements.

Keywords: Self-Etch Adhesive, Self-Adhesive Cement, Fiber Post, Root canal, Bond strength

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E&R: Etch&Rinse

SE: Self-Etch

SAC: Self-Adhesive Cement

PBS: Push-Out Bond Strength

UA: Universal Adhesive

DCC: Dual-cured cement

EDTA: Ethylenediaminetetraacetic acid

NAOCl: Sodium hypochlorite

UDMA: urethane-dimethacrylate

HEMA: 2-hydroxyethyl methacrylate

TEGDMA: triethyleneglycol-dimethacrylate

Bis-GMA: bis-phenol A glycerolate dimethacrylate

TMPTMA: Trimethylolpropane triacrylate

BPDM: Biphenyl dimethacrylate

1 INTRODUCTION

Fiber glass posts are a common and widely used option when restoring endodontically treated tooth that present an extensive loss of coronal structure. Fiber posts systems have various advantages ,among which, a good esthetic for anterior sector and an elastic modulus that similar to dentin. (1) This property allow an uniform distribution of stresses along the root.(1,2) When using fiber posts for restoring endodontically treated teeth debonding of the posts from the dentin is a frequent cause of failure. (3) Thus, bonding represents a critical element in the success of this restorations and it depends on several factors like the luting agents and the protocol used or the knowledge of the dentist. (4)

There is 5 major types of luting cement : zinc phosphate, glass-ionomer, resin-modified glass-ionomer, polycarboxylate cement and composite resin cements.

Zinc phosphate has been used for more than 150 years in dental practice. It has the advantage of being cheap, easy to manipulate, time efficient. However it is also vulnerable to microleakage, brittle and it does not adhere to the post and dentin. Glass-ionomer were introduced in the 70's, they have the advantages of adhering to dentin without the need of using adhesives or etchants in addition to being cheap and easy to use. However one of their biggest disadvantages is that they are sensitive to moisture. Resin-modified glass-ionomer were introduced in 1988 to overcome the defects of glass ionomers. They adhere to metallic post and to root canal dentin and they have a higher retention but they are more expensive than conventional glass ionomers and they requires the use of adhesives. (5)

As for the resin based luting agents and protocols, at present, three majors types can be identified, according to the adhesive system (6) : etch&rinse, self-etch and self-adhesive cements. Etch&rinse and self-etch adhesives are mainly used with a dual cure resin cement.

The adhesion to the root dentin is obtained thanks to the formation of a hybrid layer caused by the etching step and which allows the hydrophilic monomers to penetrate the dental tubules present all along the root dentin. This corresponds to the most used and best known method, the etch-and-rinse.

Several factors may influence this adhesion. Firstly, the presence of the smear layer which is mainly composed of dentin, enamel and cement debris produced when intrumentig the canal. This smear layer partially blocks the dentin tubules, which reduces the permeability of the dentin and thus lowers the infiltration of monomers. It is therefore necessary to remove it with to obtain optimal adhesion. The irrigant used during endodontic therapy will therefore have an influence on adhesion because it will make it easier to remove the smear layer, but also because the irrigants can have an influence on the dentin, particularly on its hardness, the capacity of the cement to penetrate it or its wettability. The configuration of the cavity is also to be taken into account, an unfavorable C-factor can lead to polymerization defects and create for example microleakage. Finally, the selection of the burs for the preparation of the canal as well as the endodontic sealer used will also influence the adhesion, in terms of the formation of the smear layer or the influence on the physicochemical properties of the dentin. (7)

When using E&R adhesive systems the use of a phosphoric acid is necessary before using the adhesive. Benefiting from the dissolution of the smear layer, E&R adhesive systems are commonly used and a well proven method. (1) However they require multiple steps which costs time and can lead to missteps that may cause failure, for examples microleakage or debonding. (8)

Self-etch adhesives and self-adhesive were developed to address these issues, reducing the number of steps required. The use of self-etch adhesives does not require the removal of the smear layer, in fact an acidic monomer contained in the adhesive simultaneously etch and prime the dental substrates, allowing the resins monomers to penetrates dental tubules. (2)

Self-adhesive resins were introduced in 2002, their application only requires one step, no etching or adhesive steps are required, avoiding errors on the part of the operators and allowing to reduce the chairside time (9,10). The acidic monomers are contained in the cement, they create a chemical bond when they interact with the hydroxyapatite.(11) Because of their simplicity of use, the time saved and being less technique sensitive SACs have gained in popularity. (12) However, even if several articles have shown equivalent or superior results in comparison to conventional systems, the choice of self-adhesive resins is still debated. (13)

Recently a new type of adhesive has been developed, the universal adhesive. It can be used either in SE or in E&R mode. This property allows universal adhesives to be versatile, adapting to different situations and being easy to use. (1,4)

In order to evaluate and compare the adhesion strength between posts and root canals of different luting agents and protocols, the push-out bond strength test is very often used in in vitro studies. (2,9)

2 OBJECTIVES AND HYPOTHESES

The purpose of the present study was to conduct an integrative literature review on the influence of different adhesives and resin cements on their bond strength to root canal dentin. The null hypothesis is that there are no differences in bond strength to root canal dentin between the different types of cement adhesives. It is expected that self-etch and self-adhesive cements present better PBS values than other luting systems.

3 METHODS

3.1 Information sources and search strategy

A bibliographic review was performed on PubMed (via National Library of Medicine) considering such database includes the major articles in the field of dentistry and biomaterials. The following search terms were applied: "Self-Etch Adhesive" OR "Self-Adhesive Cement" OR Self Etch Adhesive" OR "separate etch" OR "separate adhesive" OR "intraradicular bonding" AND "fiber post" OR "post" AND "bond strength" OR "dental bonding" OR "cement" AND "root canal" OR "dual cure cement" OR "adhesive". Also, a hand-search was performed on the reference lists of all primary sources and eligible studies of this systematic review for additional relevant publications. The inclusion criteria encompassed articles published in the English language, from 2011 to 2021, assessing the influence of different adhesive techniques and different types of adhesives on the bond strength in fiber posts. The eligibility inclusion criteria used for article searches also involved: *in vitro* studies, mechanical assays, meta-analyses, randomized controlled trials, animal assays, and prospective cohort studies. The exclusion criteria were the following: papers without abstract; case report with short follow-up period; articles dealing with posts treatment; articles assessing the effect of roots preparations with different techniques.

3.2 Study selection and data collection process

Studies were primarily scanned for relevance by title, and the abstracts of those that were not excluded at this stage were assessed. Three of the authors (JCMS, VF, AB) independently analyzed the titles and abstracts of the retrieved, potentially relevant articles meeting the inclusion criteria. The total of articles was compiled for each combination of key terms and therefore the duplicates were removed using Mendeley citation manager. The second step comprised the evaluation of the abstracts and non-excluded articles, according to the eligibility criteria on the abstract review. Selected articles were individually read and analyzed concerning the purpose of this study. At last, the eligible articles received a study nomenclature label, combining first author names and year of publication. The following variables were collected for this review: author's names, purpose of the study, study design, cements details, adhesives details, type of test performed, test results.

4 RESULTS

A total of 196 articles were identified in PubMed. Of these, 69 articles were duplicated. After reading and analyzing the titles and abstract of the scientific articles, 33 articles were selected and 3 of these were excluded since they did not meet the inclusion criteria. The remaining 30 studies were selected for full reading. Of these articles, 3 were excluded because they did not provide relevant information according to the purpose of the present systematic review. At last, 27 studies were included in this integrative systematic review.

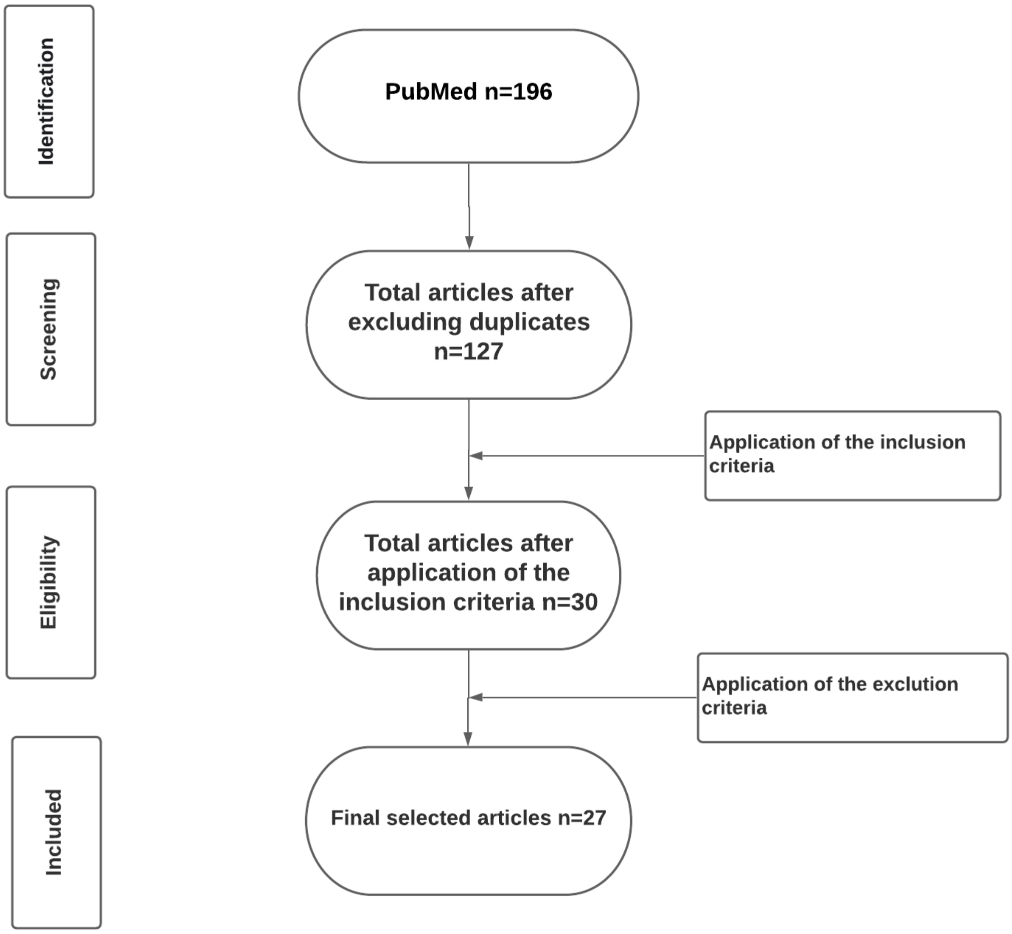

Figure 1. Flow diagram of the search strategy used in this study

Of the 27 *in vitro* studies selected, 7 (26%) were conducted on bovine teeth. The rest of the studies were conducted on human teeth. To compare the different adhesives and cements, all studies selected evaluated the bond strength by using the push-out bond test. Three studies (11%) also used thermocycling to assess the effect of aging on the different luting agents. Three studies (11%) compared UA using different modes (E&R or SE), 21 studies (77%) were conducted with SAC.

Table 1. Details gathered from the selected studies.

Author (year)	Purpose	Study design	Cement details	Adhesive details	Test Results
Spicciarelli et al. (2020)	Assess if the curing mode and the etching mode could affect the push-out bond strength.	100 single-rooted teeth Control: Prime & Bond XP (PBXP) Group 1: Prime & Bond Elect (PBE), Group 2: Prime & Bond Active (PBA) Cements (Core-X Flow) used in SE and E&R mode. Cements were cured in dark-cure and in light-cure mode Test realized: Push out bond test	UDMA, di- and tri-functional methacrylate, Barium Boron Fluoroaluminosilicate glass, CQ, photo accelerators, silicon dioxide benzoylperoxide, 70 wt.% (Core-X Flow, DENTSPLY DeTrey GmbH, Konstanz, Germany)	Penta, TCB resin, UDMA, TEGDMA, HEMA, nanofiller, camphorquinone, DMABE, Butylated benzenediol, tert-Butanol (Prime&Bond XP, DENTSPLY DeTrey GmbH, Konstanz, Germany) Mono-, di-, and trimetacrylate resins, PENTA, Diketone, Organic phosphine oxide, stabilizers, Cetylamine hydrofluoride, Aceone, Water (Prime&Bond Elect, DENTSPLY DeTrey GmbH, Konstanz, Germany) Bi- and multifunctional acrylate, phosphoric acid modified acrylate resin, initiator, stabilizer, isopropanol, water (Prime&Bond Active, DENTSPLY DeTrey GmbH, Konstanz, Germany)	The PBE and PBA obtained higher values when used in the SE mode Etching +: 9.99 MPa Etching -: 10.62 MPa Light-cured groups obtained significantly higher values Light curing -: 9.99MPa Light curing +: 10.56MPa Post space region had a significant effect on the bond strength.

Dax et al. (2020)	Analyze the pushout bond strength of a zirconia-based core buildup material in cementing two fiber posts.	80 single-rooted mandibular premolars Group I & III: PermaCem 2.0, dual-cure self-adhesive resin Group II & IV: LuxaCore Z Dual dual-cure adhesive cement Group I and II used a carbon fiber post. Group III and IV used a Glass fiber Post LuxaCore Z was used using an E&R technique Cements were cured in light-cure mode Test realized : Push out bond test	Barium glass in a Bis-GMA-based matrix of dental resisns, pigments, additives and catalysts (PemaCem 2.0, (DMG, Hamburg, Germany) barium glass, pyrogenic silicic acid, nano fillers, zirconium oxide in a Bis-GMA based resin matrix, 71 wt% (Luxacore Z, DMG, Hamburg, Germany)		Luxacore Z used with a glass fiber post showed the maximum PBS (19.50MPa ± 6.68). PermaCem 2.0 showed the lowest PBS when used with a carbon fiber post (8.38MPa ± 3.41)

Allabban et al. (2019)	Evaluate the bond strength between esthetic posts and dentin at different regions of the root canal in passive mode or push-out active mode.	20 single rooted human mandibular first premolar teeth First group used a glass fiber post. Second group used a zirconia post. Post were luted with total-etch resin cement (Variolink N, Ivoclar Vivadent) or self-adhesive resin cement (Multilink Speed, Ivoclar Vivadent) The total-etch resin cement was used with the ExciTE F DSC, Ivoclar Vivadent adhesive Test realized : Push out bond test	Dimethacrylates, Ytterbium trifluoride, Co-polymer, Glass filler, silicon dioxide, adhesive monomer, initiators, stabilizers, pigments (MultilinkSpeed, Ivoclar Vivadent, Schaan, Liechtenstein) Barium glass filler, mixed oxide, Dimethacrylates, High dispersed silica, Ytterbiumtrifluoride, Initiators, stabilizers, pigments (Variolink N, Ivoclar Vivadent, Schaan, Liechtenstein)	HEMA, dimethacrylate, phosphonic acid acrylate, highly dispersed silicone dioxide, initiators, stabilizers and potassium fluoride in an alcohol solution (ExciTe D DSC, Ivoclar Vivadent, Schaan, Liechtenstein)	The fiber post showed a higher PBS (10.1MPa) in comparison to the zirconia (6.5MPa). Total-etch adhesive showed a higher PBS (13.8MPa) than SAC (2.8). The PBS was higher in the coronal segment (10.9 MPa), followed by middle segment (7.9MPa) and apical segment (6.1 MPa).
Beldüz Kara et al. (2018)	Investigate the bond strengths of different adhesive systems and post materials on primary teeth.	120 maxillary central incisors Two main groups (total-etch, self-etch) divided into 5 subgroups : Group 1: control, nanohybrid composite resin (3M Z250) Group 2: Resin with pre-impregnated glass fiber (GrandTec, VOCO) + flowable composite resin (3M Filtek Ultimate) Group 3: Unsaturated glass fiber (fiber-splint multilayer, POLYDENTIA) + flowable composite resin (Resist, Biodental Technologies)	Bis-GMA, Bis-EMA, UDMA; TEGDMA, zirconia, sílica (0.01-3-5mm) (Z250, 3M ESPE, St. Paul, MN, USA) Bis-GMA, TEGDMA, procrylat, yterbiu fluoride, silica oxide, zirconia oxide, clusters (Filtek Ultimate, 3M ESPE, St. Paul, MN, USA) (Resist, Biodental Technologies; Sydney, NSW, Australia) (Ribbond; Seattle, WA, USA)	UDMA, BHT, HEMA Acidic adhesive monomer, 2-hydroxyethyl methacrylate, camphorquinone, nano-sized silica fillers (Futurabond M, VOCO, Cuxhaven, Germany) bis-GMA, HEMA, dimethacrylates, polyalkenoic acid copolymer, 10vol% of 5-nm silica nanofiller, initiators, water, ethanol (Adper Single Bond 2, 3M ESPE, St. Paul, MN, USA)	Highest PBS : Group 5 (20.6 ± 9.0 Mpa) and Group 1 (19.8 ± 4.1 MPa) with total-etch Lowest PBS: Group 3 (15.2 ± 9.7Mpa) with SE. Difference was found only in the total-etch adhesive system groups.

		Group 4: Polyethylene fiber (Ribbond) + flowable composite resin Group 5: Short-fiber reinforced composite resin. (EverX Posterior, Stick Ltd) Test realized: Push out bond test	Bis-GMa, TEGDMA, Silicon dioxide, barium glass, glass fiber, polymethylmethacrylate Trace, Photo initiator (EverX Posterior, Stick Ltd member of GC, Turku, Finland)		
Shafiei et al. (2018)	Evaluating the bonding performance of a universal adhesive in ER mode and SE mode with two irrigants for luting fiber posts in the root canal.	56 maxillary central incisors Group 1: NaOCl + acid etching + One-Step Plus (E&R) Group 2: NaOCl + Clearfil SE Bond (SE) Group 3: EDTA + Clearfil SE Bond (SE) Group 4: NaOCl + acid etching + All-Bond Universal (multi-mode) Group5: NaOCl + All-Bond Universal (multi-mode) Group 6: EDTA + All-Bond Universal (multi-mode) Group 7: Water + All-Bond Universal (multi-mode) All posts were luted using Duo-link. Test realized: Push out bond test	Bis-GMA, Triethylene glycol, dimethacrylate, UDMA, glass filling, glass fiber (Duo-Link, Bisco, Schaumburg, IL, USA)	Biphenyl dimethacrylate, hydroxyethyl methacrylate, acetone, glass (One-Step Plus, Bisco, Schaumburg, IL, USA) Primer: HEMA, hydrophilic, dimethacrylate, 0-MDP, toluidine, camphorquinone, water Adhesive: 10-MDP, Bis-GMA, HEMA, hydrophilic dimethacrylate, microfiller (Clearfil SE Bond, Kuraray, Osaka, Japan) 10-MDP, Dimethacrylate resisns, HEMA, ethanol, water, initiators (All-Bond Universal, Bisco, Schaumburg, IL, USA)	Highest PBS : Group 6 (15.38±3.9 MPa) Lowest PBS : Group 5 (10.17±3.5 Mpa) Bonding effectiveness of All-Bond in ER and SE modes was like control
Amiri et al. (2017)	Compare the effect of SAC and separate etch adhesive DCC on the bond strength of fiber post to dentin at	20 single rooted premolars Group 1: Rely X Unicem (SAC) Group 2: Duo-Link (separate etch adhesive) Test realized: Push out bond test	Methacrylated phosphoric acid esters, triethylene glycol dimethacrylate, substituted dimethacrylate, silanized glass powder, silane treated silica, sodium persulfate, substituted pyrimidine, calcium hydroxide (filler	Primer A :NTG-GMA, acetone, water, ethanol Primer B: BPDM, CQ, acetone, ethanol Bond: Bis-GMA, HEMA, amine activator, CQ (All Bond 2, Bisco Dental, Schaumburg, IL, USA)	Group1 showed higher PBS at the coronal (14.0 MPa), middle (10.9 MPa) and apical (9.6 MPa) segments than Group 2. Overall, the bond strength in separate etch adhesive group was higher than that in SAC group.

	different parts of the root		= 1111111172 wt%; avg. < 9.5 µm) (RelyX Unicem, 3M ESPE, St. Paul, USA) Bis-GMA, Triethylene glycol, dimethacrylate, UDMA, glass filling, glass fiber (Duo-Link, Bisco, Schaumburg, IL, USA)		
Rodrigues ey al. (2017)	Evaluate the PBS of composite resin relined glass fiber posts cemented to bovine root dentin using different adhesive cementation protocols.	18 bovine teeth Group 1: RelyX ARC with Adper Scotchbond Multi-Purpose (E&R) Group 2: RelyX Ultimate with Scotchbond Universal (SE) Group 3: RelyX Unicem 2 (SAC) Test realized: Push out bond test	Alkaline and silanated fillers, initiator components, pigments, methacrylate monomers containing phosphoric acid groups, methacrylate monomers, stabilizers (RelyX Unicem 2, 3M ESPE, St. Paul, MN, USA) Methacrylate monomers, radiopaque silanated fillers, initiator components, stabilizers and rheological additives, radiopaque alkaline (basic) fillers, pigments, fluorescence dye, dark polymerize activator for Scotchbond Universal adhesive (RelyX Ultimate, 3M ESPE, St. Paul, MN, USA) Bis-GMA, TEGDMA, zirconia silica (67.5 wt%), pigments, amine and benzoyl peroxide (RelyX ARC, 3M ESPE, St. Paul, MN, USA)	MDP phosphate monomer, dimethacrylate resins, HEMA, methacrylate-modified polyalkenoic acid copolymer, filler, ethanol, water, initiators, silane (Scotchbond Universal, 3M ESPE, St. Paul, MN, USA) Activator: ethyl alcohol, sodium benzenesulfonate Primer: water, HEMA, copolymer of acrylic and itaconic acids (Adper Scotchbond Multi Purpose, 3M ESPE, St. Paul, MN, USA)	Group 3 showed the highest PBS at cervical (7.80MPa) and apical (4.13) segments. Group 2 showed the highest PBS at medium segment (7.10 and 5.68MPa). There was no significant differences in PBS values among different cementation systems. PBS values significantly decreased with increasing depths (cervical to apical) for all adhesive cementation protocols.

Bitter et al. (2017)	Investigate the effects of various SAC on the push-out bond	144 human anterior teeth	Bis-GMA, UDMA, DDDMA, BHT, dibenzoyl peroxide, CQ, silica, barium borosilicate glass ceramic,	Organic acids, Bis-GMA, HEMA, TMPTMA, BHT, ethanol, fluorides,	Group 5 and Group 4 showed the higher PBS : (14.6 ±5.8 MPa) and (14.1±6.8 MPa). Those differences are significantly higher

	strengths and nanoleakage expression immediately and after one year of aging.	Group 1 (control) : Rebilda DC with Futurabond DC (SE) Group 2: BiFix SE (SAC) Group3: Speed Cem (SAC) Group4: RelyX Unicem2 (SAC) Group5: Smart Cem2 (SAC) Group6: Clearfil SA Cement (SAC) Test realized: Push out bond test	accelerators, 71 wt% (Rebilda DC, VOCO, Cuxhaven, Germany) UDMA, GDMA, catalyst, initiator (BiFix SE, VOCO, Cuxhaven, Germany) DMA, acidic monomers, barium glass, ytterbium trifluoride, copolymer, silicon dioxide, initiators, stabilizers, color pigments (SpeedCem, Ivoclar Vivadent, Schaan, Liechtenstein) Alkaline and silanated fillers, initiator components, pigments, methacrylate monomers containing phosphoric acid groups, methacrylate monomers, stabilizers (RelyX Unicem 2, 3M ESPE, St. Paul, MN, USA) UDMA, DMA, TMA, phosphoric acid– modified acrylate resin, PENTA, proprietary photoinitiating system, proprietary self-cure initiating system (Smart Cem2, Dentsply Ballaigues, Switzerland) Bis-GMA, TEGDMA, MDP, hydrophobic aromatic and aliphatic DMA, silanated barium glass filler, DLcamphorquinone, benzoyl peroxide, initiator, pigments	CQ, amine, catalysts (Futurabond DC, VOCO, Cuxhaven, Germany)	compared to Group 2 and Group 1 but no from Group 3. Group 6 showed a significantly lower PBS (6.1±4.6 MPa) than the others. Bond strength was significantly affected by the location inside the root canal. Bond strength was not significantly affected by aging.

			(Clearfil SA Cement, Kuraray Dental, Osaka, Japan)		
Almulhim et al. (2016)	Compare the PBS of two resin cement systems (total-etch versus SAC) for cementing fiber-reinforced composite posts	60 bicuspid single rooted teeth Group1 (control): RelyX Ultimate (total-etch) without thermocycling Group2: RelyX Ultimate (20,000 cycles) Group 3: RelyX Ultimate (40, 000 cycles) Group4: RelyX Unicem (SAC) without thermocycling Group5: RelyX Unicem (20,000 cycles) Group6: RelyX Unicem (40,000 cycles) Test realized: Push out bond test	Methacrylated phosphoric acid esters, triethylene glycol dimethacrylate, substituted dimethacrylate, silanized glass powder, silane treated silica, sodium persulfate, substituted pyrimidine, calcium hydroxide (filler = 72 wt%; avg. < 9.5 μm) (RelyX Unicem, 3M ESPE, St. Paul, USA) Methacrylate monomers, radiopaque silanated fillers, initiator components, stabilizers and rheological additives, radiopaque alkaline (basic) fillers, pigments, fluorescence dye, dark polymerize activator for Scotchbond Universal adhesive (RelyX Ultimate, 3M ESPE, St. Paul, MN, USA)		There was not any significant differences between all groups. Group2 and Group5 showed higher PBS than Group3 and Group6, regarding aging effect.
Durski et al. (2016)	Evaluate the PBS of two different adhesive cements (total etch and SAC) for glass fiber post cementation using two different techniques.	60 single rooted premolars Group1: RelyX ARC (total-etch) + microbrush Group2: RelyX ARC + elongation tip Group3: RelyX Unicem (SAC) + microbrush Group4: RelyX Unicem +elongation tip	Bis-GMA, TEGDMA, zirconia silica (67.5 wt%), pigments, amine and benzoyl peroxide (RelyX ARC, 3M ESPE, St. Paul, MN, USA) Methacrylated phosphoric acid esters, triethylene glycol dimethacrylate, substituted dimethacrylate, silanized glass powder, silane treated silica,		Group 3 and 4 showed significantly higher PBS in all thirds : 7.23 ±3.07;11.32 ± 2.55 ;14.81 ±3.45 (with the microbrush) and 9.42 ± 1.21; 14.97 ±1.94; 18.68 ± 2.01 (with elongation tip). PBS were significantly higher wih the elongation tip

		Group5: RelyX Unicem + etching + microbrush Group6: RelyX Unicem+ etching+ elongation tip Test realized: Push out bond test	sodium persulfate, substituted pyrimidine, calcium hydroxide (filler = 72 wt%; avg. < 9.5 μm) (RelyX Unicem, 3M ESPE, St. Paul, USA)		PBS were higher when adding an additional conditioning step (Group5 and 6) with RU.
Daleprane et al. (2016)	Assess the effects of anatomic root levels to reach the canal and different resin cements on the bond strength of fiber glass posts along the canal.	135 bovine teeth Group1: RelyX ARC +Adper Scotchbond Multi-plus (E&R) Group2: RelyX U200 (SAC) Group3: C&B + All-Bond2 (autopolymerizing cement with E&R) Test realized : Push out bond test	BASE: glass fiber, methacrylate phosphoric acid esters, triethylene glycol dimethacrylate, silane-treated silica, sodium persulfate CATALYST: glass fiber, substitute dimethacrylate, silane-treated silica, sodium ptoluenesulfonate, calcium hydroxide (RelyX U200, 3M ESPE, St. Paul, MN, USA) Bis-GMA, TEGDMA, zirconia silica (67.5 wt%), pigments, amine and benzoyl peroxide (RelyX ARC, 3M ESPE, St. Paul, MN, USA) BASE: Bis-GMA dimethacrylate, silica, fused glass, sodium fluoride. CATALYST: Silica, bis-GMA, triethylene glycol dimethacrylate. (C&B, Bisco, Schaumburg, IL, USA)	PRIMER A: acetone, ethanol, NTG-GMA. PRIMER B: BPDM, photoinitiator acetone (All-Bond 2, Bisco, Schaumburg, IL, USA) ACTIVATOR: ethyl alcohol, sodium benzenesulfinate. PRIMER: water, 2-hydroxyethylmethacrylate, copolymer of polycarboxylic acid. CATALYST: (1-methyl ethylidene) bis[4,1-phenylene oxi (2-hydroxy-3, 1,-propanediyl)] bis methacrylate, 2-hydroxyethyl methacrylate, benzoyl peroxide (Adper Scotchbond Multi-plus, , 3M ESPE, St. Paul, MN, USA)	There was no significant differences between all resins for the same anatomic root level. The coronal bond strength was lower than the apical (P=.001) and middle (P=.021) bond strengths for all cements.
Oskoee et al. (2016)	Compare the effect of different bonding strategies on PBS of fiber posts to intraradicular dentin.	72 single rooted teeth Group1: self-adhesive resin cement (SAC) Group2: dual-cure resin (DCC) Group3: universal adhesive in the E&R mode and SAC Group4: universal adhesive in the SE mode and SAC	Base: Bis-GMA, Triethyleneglycol Dimethacrylate, Glass filler Catalyst: Bis-GMA, Triethyleneglycol Dimethacrylate, Glass filler (Duo Link Universal, Bisco, Schaumburg, IL, USA) Paste A:Bis-GMA,TEGDMA, MDP, dimethacrylate, Silanated barium	MDP Phosphate Monomer, Dimethacrylate resins, HEMA, Vitrebond Copolymer, Filler, Ethanol, Water, Initiators, silane (SingleBond Universal, 3M ESPE, St. Paul, MN, USA)	PBS between Group 1 (7.95 ± 3.31) and Group 2 (8.41a ±3.20) are not significantly different. PBS for Group 4 (13.45b ±4.70) was significantly higher than Group 1 and Group 3 (10.22± 5.38).

		Group5: universal adhesive in the E&R mode and DCC Group6: universal adhesive in the SE mode and DCC DCC : Duo Link Universal cement SAC : ClearfilSA Luting cement Universal Adhesive : Single Bond Universal Test realized : Push out bond test	glass filler, Silanated colloidal silica, dl-amphorquinone, Benzoylperoxide, Initiators Paste B: Bis-GMA , imethacrylate, Silanated barium glass filler, Silanated colloidal silica, Surface treated sodium fluride, Accelerators, Pigments (Clearfil SA, Kuraray Noritake Dental Inc, NY, USA)		PBS for Group 2 was significantly lower than Group 5(11.88 ±5.75 and 6(11.41 ±4.19). There is no differences between Group 5 and 6.
Ebrahimi et al. (2014)	Evaluate the push-out bond strengths of a glass fiber post to different root canal regions with the use of two adhesives with light- and dual-cure polymerization modes	40 maxillary central incisors Group1: Excite Light-cure (E&R) Group2:Excite Dual-cure (E&R dual cure) Group3:AdheSE Light-cure (SE) Group4:AdheSE Dual-cure (SE dual cure) Posts were luted with VarioLink II Test realized : Push out bond test	Hydroxyethylmethacrylate, Dimethacrylate, Highly dispersible silicon dioxide, Initiators, Stabilizers (Variolink II, Ivoclar Vivadent, Schaan, Liechtenstein)	Phosphonic acid acrylate, Hydroxyethyl dimethacrylate, Methacrylate, Highly dispersible silicon dioxide, Ethanol (solvent), Catalysts and stabilizers (Excite, Ivoclar Vivadent, Schaan, Liechtenstein) HEMA, dimethacrylates, phosphonic acid acrylate, silicon dioxide, initiators, stabilisers, alcohol (Excite DSC, Ivoclar Vivadent, Schaan, Liechtenstein) Bis acrylamide, Phosphonic acid acrylate, Initiators, Stabilizers, Water (AdheSE, (Excite, Ivoclar Vivadent, Schaan, Liechtenstein)	Group4 showed the highest PBS (15.54 ± 6.90 MPa). Group1 showed the lowest PBS (10.07 ± 7.45 MPa). The only significant differences was between Group1 and 4.

Bitter et al. (2014)	Analyze four different post-and-core-systems with two different adhesive approaches (SE and E&R).	80 human anterior teeth Group1: Rebilda Post + Rebilda DC + Futurabond DC (SE) Group2: Luxapost + Luxacore Z + Luxabond Prebond and Luxabond A+B (E&R) Group3: X Post + Core X Flow + XP Bond and Self Cure Activator (E&R) Group4: FRC Postec + MultiCore Flow + AdheSE DC (SE) Test realized : Push out bond test	Bis-GMA, UDMA, DDDMA, BHT, dibenzoyl peroxide, CQ, silica, barium borosilicate glass ceramic, accelerators, 71 wt% (Rebilda DC, VOCO, Cuxhaven, Germany) Barium glass, pyrogenic silicic acid, nano fillers, zirconium oxide in a Bis-GMA based resin matrix, 71 wt% (Luxacore Z, DMG, Hamburg, Germany) UDMA, di- and tri-functional methacrylates, Barium Boron Fluoroaluminosilicate glass, CQ, photoaccelerators, silicon dioxide benzoylperoxide, 70 wt% (Core-X Flow, DENTSPLY DeTrey GmbH, Konstanz, Germany) Dimethacrylate, barium glass, fillers, Ba-Al-fluorosilicate glass, silicon dioxide, ytterbium trifluoride, catalysts, stabilizer, pigments Base: 54.9 wt% Catalyst: 54.4 wt% (Multicore DC, Ivoclar Vivadent, Schaan, Liechtenstein)	Organic acids, Bis-GMA, HEMA, TMPTMA, BHT, ethanol, fluorides, CQ, amine, catalysts (Futurabond DC, VOCO, Cuxhaven, Germany) Ethanol Arylsulfinate solution Luxabond A: hydrophile Bis-GMA based resin matrix, catalyst Luxabond B : hydrophile BIS-GMA based resin matrix, benzoyl peroxide (Prebond Luxabond, DMG, Hamburg, Germany) PENTA, TCB, HEMA, TEGDMA, UDMA, tert-butanol, nanofiller, CQ, stabilizer; Self Cure Activator: HEMA, UDMA, Catalyst, aromatic sodium sulfinate, Photoinitiator, Stabilizers, Acetone, Water (XP Bond, Dentsply DeTrey, Konstanz, Germany) Bis acrylamide, Phosphonic acid acrylate, Initiators, Stabilizers, Water (AdheSE, (Excite, Ivoclar Vivadent, Schaan, Liechtenstein)	Group3 showed the lowest PBS (7.7 (4.4) MPa). It is significantly different than Group 2 (14.2 (8.7) MPa) and Group 1 (13.3 (3.7) MPa) but not from Group 4 (11.5 (3.5) MPa). Bond strengths of the four investigated post-and-core systems inside the root canal were not affected by the adhesive approach.
Nova et al. (2013)	Evaluating the effects of a SE and various SAC on the PBS.	100 bovine incisors Group1: roots prepared with RelyX Fiber post drill size one (Ø 1.3 mm) Group2: roots prepared with drill size three (Ø 1.9 mm) to obtain different cement thickness	Liquid: dimethacrylate (50–60), powder: fluoro-alumino-silicate-glass (100) (G-Cem, GC Corporation, Tokyo, Japan) Uncured methacrylate ester monomers		RelyX Unicem showed a significantly higher PBS in both groups (530.51±95.42N and 573.65±71.66N). Maxcem Elite showed a significantly lower PBS in group 2.

		In each groups 5 cements were used: G-Cem, Maxcem Elite, RelyX Unicem, SmartCem 2, Multilink Automix (Control, SE) Test realized : Push out bond test	(19–40), fillers (69) (Maxcem Elite, Kerr Company, Orange, USA) Methacrylated phosphoric acid esters, triethylene glycol dimethacrylate, substituted dimethacrylate, silanized glass powder, silane treated silica, sodium persulfate, substituted pyrimidine, calcium hydroxide (filler = 72 wt%; avg. < 9.5 μm) (RelyX Unicem, 3M ESPE, St. Paul, USA) Urethane dimethacrylate resin (<15), fillers (69) (SmartCem2, DENTSPLY Caulk, Milford, USA) Base: Dimethacrylate and HEMA (30), fillers (45.5) (Multilink Automix, Ivoclar Vivadent, Schaan, Liechtenstein)		
Aleisa et al. (2013)	Investigate the tensile bond strength of glass fiber posts luted to premolar teeth with 6 resin composite luting agents.	96 single rooted human premolars Group V: Variolink II + Excite DSC (E&R) Group A: RelyX ARC + Scotchbond Multipurpose Plus Activator (E&R) GroupN: Multilink N (SE) GroupU: RelyX Unicem (SAC) GroupP: ParaCore + ParaBond Adhesive A/B (SE) GroupF: MultiCore Flow (SE) Test realized: Push out bond test	Hydroxyethylmethacrylate, Dimethacrylate, Highly dispersible silicon dioxide, Initiators, Stabilizers (Variolink II, Ivoclar Vivadent, Schaan, Liechtenstein) Bis-GMA, TEGDMA, zirconia silica (67.5 wt%), pigments, amine and benzoyl peroxide (RelyX ARC, 3M ESPE, St. Paul, MN, USA) Monomer matrix is composed of dimethacrylate and HEMA.	HEMA, dimethacrylates, phosphonic acid acrylate, silicon dioxide, initiators, stabilisers, alcohol (Excite DSC, Ivoclar Vivadent, Schaan, Liechtenstein) Activator: ethyl alcohol, sodium benzenesulfonate Primer: water, HEMA, copolymer of acrylic and itaconic acids (Adper Scotchbond Multi	Group P showed the highest PBS (280 ±69 N). Group N showed the lowest PBS (119 ±29 N) The PBS for Group U, Group P and Group F were significantly higher.

			Inorganic fillers are barium glass, ytterbium trifluoride, spheroid mixed oxide. (Multilink N, Ivoclar Vivadent, Schaan, Liechtenstein) Methacrylates, Fluoride, Barium glass, Amorphous silica (ParaCore, Coltene/Whaledent, Alstattan, Switzerland) Dimethacrylate, barium glass, fillers, Ba-Al-fluorosilicate glass, silicon dioxide, ytterbium trifluoride, catalysts, stabilizer, pigments Base: 54.9 wt% Catalyst: 54.4 wt% (Multicore DC, Ivoclar Vivadent, Schaan, Liechtenstein)	Purpose, 3M ESPE, St. Paul, MN, USA) Methacrylates, Polyalkenoate, Initiators, Ethanol, Water, Initiator (ParaBond Adhesive A/B, Coltene/Whaledent, Alstattan, Switzerland)	
Juloski et al. (2013)	Assess the post retentive potential of experimental SAC when used alone and in combination with a SE adhesive.	24 single rooted and single canal human premolars. Group1: GAM-200 (experimental SAC) Group2: GAM-200 with Gradia Core Self-Etching Bond (SE) Group3: Gradia Core dual-cured cement + Gradia Core Self-Etching Bond (SE) Group4: G-CEM Automix (SAC) Test realized: Push out bond test	UDMA, dimethacrylates, fluoroaminosilicate glass, phosphoricacid ester monomer, silicon dioxide, initiators, stabilizers, and pigment (GAM-200, GC, Tokyo, Japan) UDMA, dimethacrylates, fluoroaminosilicate glass, silicon dioxide, initiator, inhibitor, pigment (Gradia Core dual-cured luting cement, GC, Tokyo, Japan) UDMA, dimethacrylates, fluoroaminosilicateglass, phosphoric acid ester monomer,	Distilled water, ethanol, 4-methacryloxyethyltrimellitate anhydride, dimethacrylates, silicon dioxide, and initiator (Gradia Core Self-Etching Bond, GC, Tokyo, Japan)	Group 2 showed a significantly higher PBS (15.87 ± 4.68 MPa). Group1 showed a PBS (7.48 ± 4.35 MPa) comparable to Group 3 (8.77 ± 4.58 MPa) and Group 4 (6.79 ± 3.68 MPa).

			silicon dioxide, initiators/stabilizers, and pigment (G-Cem Automix, GC, Tokyo, Japan)		
Dimitrouli et al. (2012)	Compare the push-out strength of glass fiber posts dependent on the resin cement.	100 human teeth Group1 (control): DT Light SL fiber post with Variolink II + Excite DSC (E&R) Group2: DT Light SL with Maxcem Elite (SAC) Group3: DT Light SL with iCem (SAC) Group4: DT Light SL with BifixSE (SAC) Group5: RelyX Fiber Post with RelyX Unicem (SAC) Test realized: Push out bond test	Hydroxyethylmethacrylate, Dimethacrylate, Highly dispersible silicon dioxide, Initiators, Stabilizers (Variolink II, Ivoclar Vivadent, Schaan, Liechtenstein) GPDM, co-monomers (mono-, di-, and tri- functional methacrylate monomers, water, acetone, and ethanol. Inert materials and ytterbium fluoride. (Maxcem Elite, Kerr Company, Orange, USA) Acidified urethane and di-, tri, multifunctional acrylate monomers. (Heraeus Kulzer, Hanau, Germany) UDMA, GDMA, catalyst, initiator (BiFix SE, VOCO, Cuxhaven, Germany) Methacrylated phosphoric acid esters, triethylene glycol dimethacrylate, substituted dimethacrylate, silanized glass powder, silane treated silica, sodium persulfate, substituted pyrimidine, calcium hydroxide	HEMA, dimethacrylates, phosphonic acid acrylate, silicon dioxide, initiators, stabilisers, alcohol (Excite DSC, Ivoclar Vivadent, Schaan, Liechtenstein)	Group 4 showed the highest PBS before thermocycling (22.5±10.4 MPa). It was significantly higher than Group 5 and Group 2 PBS. Group1 showed the second highest PBS before TC (16.5± 6.4 MPa). The difference compared to other groups is not statistically significant.

			(filler = 72 wt%; avg. < 9.5 μm) (RelyX Unicem, 3M ESPE, St. Paul, USA)		
Faria-e Silva et al. (2012)	Investigating the effect of coinitiator solutions and SAC on the early retention of glass-fiber posts.	40 bovine incisors Group1: RelyX ARC + SingleBond 2 Group2: RelyX ARC+ Scotchbond Multipurpose Plus Activator + primer Group3: RelyX ARC + Scotchbond Multipurpose Plus Activator + primer + catalyst Group4: RelyX Unicem (SAC) Test realized : Push out bond test	Bis-GMA, TEGDMA, zirconia silica (67.5 wt%), pigments, amine and benzoyl peroxide (RelyX ARC, 3M ESPE, St. Paul, MN, USA) Methacrylated phosphoric acid esters, triethylene glycol dimethacrylate, substituted dimethacrylate, silanized glass powder, silane treated silica, sodium persulfate, substituted pyrimidine, calcium hydroxide (filler = 72 wt%; avg. < 9.5 μm) (RelyX Unicem, 3M ESPE, St. Paul, USA)	bis-GMA, HEMA, dimethacrylates, ethanol, water, photoinitiator, methacrylate functional copolymer of poluacrylic and poly(itaconis) acids, 10% 5-nm-diameter spherical silica particles (Single Bond 2, 3M ESPE, St. Paul, USA) Activator: ethyl alcohol, sodium benzenesulfonate Primer: water, HEMA, copolymer of acrylic and itaconic acids (Adper Scotchbond Multi Purpose, 3M ESPE, St. Paul, MN, USA)	Group3 showed a significantly higher PBS. Group 4 showed the second higher PBS. Group 2 and 1 had similar PBS.
Calixto et al. (2012)	Evaluating the bond strength of luting systems for bonding glass fiber posts to root canal dentin.	40 bovine incisors Group1: C&B Cement (E&R) Group2: RelyX ARC (E&R) Group3: Multilink (SE) Group4: Panavia F2.0(SE) Group5: RelyX U100 (SAC) Test realize : Push out bond test	BASE: Bis-GMA dimethacrylate, silica, fused glass, sodium fluoride. CATALYST: Silica, bis-GMA, triethylene glycol dimethacrylate. (C&B cement, Bisco Inc, Schaumburg, IL, USA) Bis-GMA, TEGDMA, zirconia silica (67.5 wt%), pigments, amine and benzoyl peroxide (RelyX ARC, 3M ESPE, St. Paul, MN, USA)	Activator: ethyl alcohol, sodium benzenesulfonate Primer: water, HEMA, copolymer of acrylic and itaconic acids (Adper Scotchbond Multi Purpose, 3M ESPE, St. Paul, MN, USA)	PBS for Group1 to 4 were no significantly different. G5 showed a significantly lower PBS. The lowest PBS were found in the apical thirds.

			Pastes of dimethacrylates, hydroxyethyl methacrylate (HEMA), inorganic fillers, ytterbium trifluoride initiators, stabilizers and pigments, dimethacrylates, HEMA, benzoylperoxide (Multilink, Ivoclar Vivadent) AG, Schaan, Liechtenstein) Hydrophobic aromatic dimethacrylate, hydrophobic aliphatic dimethacrylate, hydrophilic aliphatic dimethacrylate, silanated barium glass filler, catalysts, accelerators, pigments, others, sodium fluoride (Panavia F2.0, Kuraray Co, Ltd, Tokyo, Japan) Glass powder, methacrylated phosphoric acid esters, triethylene glycol dimethacrylate (TEGDMA), silane-treated silica, sodium persulfate, glass powder, substituted dimethacrylate, silane-treated silica, sodium p-toluene sulfinate, calcium hydroxide(RelyX U100, 3M, St. Paul, MN, USA)		
Sterzenbach et al. (2012)	Comparing PBS of fiber-posts luted with different adhesive approaches to root canal dentin.	40 human maxillary central incisors Group1: DentinBuild+DentinBond (E&R) Group2: Core-X Flow + XP Bond (E&R) Group3: RelyX Unicem (SAC)	(DentinBuild Komet, Gebr. Brasseler, Lemgo, Germany) UDMA, di- and tri-functional methacrylates, Barium Boron Fluoroaluminosilicate glass, CQ, photoaccelerators, silicon dioxide	(DentinBond Komet, Gebr. Brasseler, Lemgo, Germany) PENTA, TCB, HEMA, TEGDMA, UDMA, tert-butanol, nanofiller, CQ, stabilizer; Self Cure Activator: HEMA, UDMA, Catalyst, aromatic	Group3, 4 and 2 showed significantly higher PBS than Group5 and 1.

		Group4: SmartCem2 (SAC) Group5: Panavia F 2.0 + ED Primer II (SE) Test realized: Push out bond test	benzoylperoxide, 70 wt% (Core-X Flow, DENTSPLY DeTrey GmbH, Konstanz, Germany) Methacrylated phosphoric acid esters, triethylene glycol dimethacrylate, substituted dimethacrylate, silanized glass powder, silane treated silica, sodium persulfate, substituted pyrimidine, calcium hydroxide (filler = 72 wt%; avg. < 9.5 µm) (RelyX Unicem, 3M ESPE, St. Paul, USA) UDMA, DMA, TMA, phosphoric acid– modified acrylate resin, PENTA, proprietary photoinitiating system, proprietary self-cure initiating system (Smart Cem2, Dentsply Ballaigues, Switzerland) Hydrophobic aromatic dimethacrylate, hydrophobic aliphatic dimethacrylate, hydrophilic aliphatic dimethacrylate, silanated barium glass filler, catalysts, accelerators, pigments, others, sodium fluoride (Panavia F2.0, Kuraray Co, Ltd, Tokyo, Japan)	sodium sulfinate, Photoinitiator, Stabilizers, Acetone, Water (XP Bond, Dentsply DeTrey, Konstanz, Germany) Primer A :2-Hydroxyethyl methacrylate, 10-methacryloyloxydecil dihydrogen phosphate, N-methacryloyl-5aminosalicylic acud, n,n'-diehanil -ptoluidine, water Primer B : N-methacryloyl- 8-aminosalicylic acid, sodiul benzene sulphinate, n,n'-diethanol p-toluidine, water (Kuraray Europe, Frankfurt am Main, Germany)	

Bergoli et al. (2012)	Evaluate the effect of mechanical cycling and cementation strategies on the PBS between fiber posts and root dentin using three resin cements.	80 bovine mandibular teeth Group1: Scotchbond Multi Purpose + RelyX ARC (E&R) Group2: Scotchbond Multi Purpose + RelyX ARC + mechanical cycling Group3: AdheSE + Multilink Automix Group4: AdheSE + Multilink Automix + mechanical cycling Group5: phosphoric acid + RelyX U100 (SAC) Group6: phosphoric acid + RelyX U100 + mechanical cycling Group7: RelyX U100 Group8: RelyX U100 + mechanical cycling Test realized : Push out bond test	Glass powder, methacrylated phosphoric acid esters, triethylene glycol dimethacrylate (TEGDMA), silane-treated silica, sodium persulfate, glass powder, substituted dimethacrylate, silane-treated silica, sodium p-toluene sulfinate, calcium hydroxide(RelyX U100, 3M, St. Paul, MN, USA) Bis-GMA, TEGDMA, zirconia silica (67.5 wt%), pigments, amine and benzoyl peroxide (RelyX ARC, 3M ESPE, St. Paul, MN, USA) Base: Dimethacrylate and HEMA (30), fillers (45.5) (Multilink Automix, Ivoclar Vivadent, Schaan, Liechtenstein)	Activator: ethyl alcohol, sodium benzenesulfonate Primer: water, HEMA, copolymer of acrylic and itaconic acids (Adper Scotchbond Multi Purpose, 3M ESPE, St. Paul, MN, USA) Bis acrylamide, Phosphonic acid acrylate, Initiators, Stabilizers, Water (AdheSE, (Excite, Ivoclar Vivadent, Schaan, Liechtenstein)	Groups using RelyX U100 (5, 6,7 and 8) and RelyX ARC (1 and 2) showed higher PBS (G8: 11.4±3.7 MPa, G2: 11.3±3.1 MPa). RelyX U100 also showed the lower polymerization stress values.
Kahnamouei et al. (2012)	Investigate the PBS of quartz fiber posts to root dentin with the use of different total-etch and SAC.	90 single rooted human premolars total-etch Group1: Nexus NX3 + Optibond Solo Plus Group2: Duo-link + All Bond 3 Group3: RelyX ARC + Single Bond SAC Group4: Maxcem Group5: BisCem Group6: RelyX Unicem Test realized: Push out bond test	ethacrylate ester monomer, mineral fillers, initiators, stabilizers, pigments, radiopaque agent (Nexus NX3, Kerr, Orange, CA, USA) Bis-GMA, Triethylene glycol, dimethacrylate, UDMA, glass filling, glass fiber (Duo-Link, Bisco, Schaumburg, IL, USA) Bis-GMA, TEGDMA, zirconia silica (67.5 wt%), pigments, amine and benzoyl peroxide (RelyX ARC, 3M ESPE, St. Paul, MN, USA)	Ethyl alcohol, alkyl dimethacrylate resins,barium aluminoborosilicate glass, fumed silica, sodium hexafluorosilicate 0.5-1%, Bis-GMA, 2-HEMA, 10-methacryloyloxy -decym dihydrogenphosphate, hydrophobic aliphatic methacrylate, colloidal silica, camphorquinone, initiators, accelerators (Optibond Solo Plus, Kerr, Orange, CA, USA) PRIMER A: acetone, ethanol, NTG-GMA. PRIMER B: BPDM, photoinitiator acetone (All Bond 3, BISCO, Schaumburg, IL, USA)	Group6 showed the highest PBS (13.91±5.99 MPa) and Group3 showed the lowest (7.04±3.06 MPa). In general SAC showed higher PBS and total-etch showed more uniform bond strength.

			GPDM, functional metacrilates, initiators, stabilizers, barium glass and aluminium–fluoride–silicate glass. (MaxCem Kerr, Orange, CA, USA) Bisphenol-A glycidyl dimethacrylate, uncured dimethacrylate monomer, glass filler Phosphate acidic monomer, glass fillers (BisCem, BISCO, Schaumburg, IL, USA) Methacrylated phosphoric acid esters, triethylene glycol dimethacrylate, substituted dimethacrylate, silanized glass powder, silane treated silica, sodium persulfate, substituted pyrimidine, calcium hydroxide (filler = 72 wt%; avg. < 9.5 μm) (RelyX Unicem, 3M ESPE, St. Paul, USA)	bis-GMA, HEMA, dimethacrylates, ethanol, water, photoinitiator, methacrylate functional copolymer of poluacrylic and poly(itaconis) acids, 10% 5-nm-diameter spherical silica particles (Single Bond, 3M ESPE, St. Paul, MN, USA)	
Soares et al. (2012)	Evaluate the effect of luting agent and fiberglass post design on bond strength to root dentine at different depths within the canal.	90 single rooted teeth Group1: RelyX ARC + Scotchbond Multi-Purpose (E&R) Group2: RelyX Unicem (SAC) Group3: MaxCem (SAC) Group4: Cement-post + Scotchbond Multi-Purpose (E&R) Test realized: Push out bond test	Bis-GMA, TEGDMA, zirconia silica (67.5 wt%), pigments, amine and benzoyl peroxide (RelyX ARC, 3M ESPE, St. Paul, MN, USA) Methacrylated phosphoric acid esters, triethylene glycol dimethacrylate, substituted dimethacrylate, silanized glass powder, silane treated silica,	Activator: ethyl alcohol, sodium benzenesulfonate Primer: water, HEMA, copolymer of acrylic and itaconic acids (Adper Scotchbond Multi-Purpose, 3M ESPE, St. Paul, MN, USA)	Overall, Group2 showed a significantly higher PBS than other groups (14.5 (3.3) MPa in the middle section). Group3 showed the lowest PBS (3.2 (0.1) MPa in the apical section).

			sodium persulfate, substituted pyrimidine, calcium hydroxide (filler = 72 wt%; avg. < 9.5 μm) (RelyX Unicem, 3M ESPE, St. Paul, USA) GPDM, functional metacrilates, initiators, stabilizers, barium glass and aluminium–fluoride–silicate glass. (MaxCem Kerr, Orange, CA, USA) Base paste: barium glass ceramic, pirogenic silica, Bis-GMA, TEDMA, BHT, accelerators and pigments Catalyst paste: barium glass ceramic, pirogenic silica, Bis-GMA, TEDMA, benzoyl peroxide and stabilizers (Cement-Post, Aˆ ngelus, Londrina, PR, Brazil)		
Lopes et al. (2012)	Evaluate bond strength between translucent fibre posts and intraradicular dentin using a DCC (AllCem) or SAC (Multilink).	32 single rooted teeth Group1: White Post DC fibre post + AllCem Group2: FRC Postec Plus fibre post + AllCem Group3: White Post DC fibre post + Multilink Group4: FRC Postec Plus fibre post + Multilink Test realized: Push out bond test	Bis-GMA, Bis-EMA, TEGDMA co-initiators, initiators (camphorquinone, dibenzoyl peroxide), stabilisers. Barium-aluminum-silicate glass microfillers and silicon dioxide nanofillers. 68% wt. inorganic fillers (All Cem, FGM Joinville, Brazil) Pastes of dimethacrylates, hydroxyethyl methacrylate (HEMA), inorganic fillers, ytterbium trifluoride initiators, stabilizers and pigments, dimethacrylates, HEMA,	HEMA, dimethacrylates, phosphonic acid acrylate, silicon dioxide, initiators, stabilisers, alcohol (Excite DSC, Ivoclar Vivadent, Schaan, Liechtenstein)	Group3 showed the highest PBS and Group4 showed the lowest but there were no significant differences between groups.

			benzoylperoxide 39.7% vol inorganic filler (Multilink, Ivoclar Vivadent		
Amaral et al. (2011)	Evaluate the effects of mechanical cycling on resin PBS to root dentin, using two strategies for fiber post cementation	40 bovine roots Group1 and 2: RelyX ARC + Scotch Bond Multi-Purpose Plus Group3 and 4: RelyX U100 Test realized: Push out bond test	Bis-GMA, TEGDMA, zirconia silica (67.5 wt%), pigments, amine and benzoyl peroxide (RelyX ARC, 3M ESPE, St. Paul, MN, USA) Glass powder, methacrylated phosphoric acid esters, triethylene glycol dimethacrylate (TEGDMA), silane-treated silica, sodium persulfate, glass powder, substituted dimethacrylate, silane-treated silica, sodium p-toluene sulfinate, calcium hydroxide(RelyX U100, 3M, St. Paul, MN, USA)	Activator: ethyl alcohol, sodium benzenesulfonate Primer: water, HEMA, copolymer of acrylic and itaconic acids (Adper Scotchbond Multi-Purpose, 3M ESPE, St. Paul, MN, USA)	Group3 showed the highest PBS (11 ± 1.6 MPa), Group2 showed the lowest PBS (6.6 ± 2.9). Mechanical cycling did not affect significantly the push out test.
Dimitrouli et al. (2011)	Analyze the PBS of two fiber post systems/resin cements depending on the root canal filling.	160 human teeth Tooth were divided in 4 groups: gutta-percha/AH Plus (GP), gutta-percha/Guttaflow (GF), pre-existing root canal filling (PRF), and without root canal filling (WRF). Posts were inserted using Variolink II or RelyX Unicem Half of the teeth were thermocycled Test realized: Push out bond test	Hydroxyethylmethacrylate, Dimethacrylate, Highly dispersible silicon dioxide, Initiators, Stabilizers (Variolink II, Ivoclar Vivadent, Schaan, Liechtenstein) Methacrylated phosphoric acid esters, triethylene glycol dimethacrylate, substituted dimethacrylate, silanized glass powder, silane treated silica, sodium persulfate, substituted pyrimidine, calcium hydroxide (filler = 72 wt%; avg. < 9.5 μm)	HEMA, dimethacrylates, phosphonic acid acrylate, silicon dioxide, initiators, stabilisers, alcohol (Excite DSC, Ivoclar Vivadent, Schaan, Liechtenstein)	The group using Variolink II, without root canal filling and not thermocycled showed the highest PBS (**16.5±6.4 MPa)**

			(RelyX Unicem, 3M ESPE, St. Paul, USA)		

The main outcomes from the selected articles are briefly described as follow:

- Regarding the universal adhesives, they showed similar results when compared to controls, using SE or E&R modes (1). When comparing SE and E&R mode, UA showed better results when used in SE mode (4,14). However, the irrigant used influenced the performance, as shown by Shafiei et al. (1) SE mode showed better performance with EDTA and lower performance when using NaOCl, in comparison to E&R mode.
- Within the 21 studies using SAC, 6 reported lower values of PBS for the SAC, compared to E&R or SE (15–20) : 19.50 ± 6.68 MPa for the E&R against 10.89 ± 3.78 MPa for the SAC (15); 11.8 ± 2.6 MPa for the E&R and 8.7 ± 2.0 MPa for the SE against 6.7 ± 1.2 MPa for the SAC (19).

  On the contrary, 10 studies reported higher PBS values for the SAC when compared to E&R and SE (6,8,10–12,14,21–24) : 22.17 ± 2.83 MPa for the SAC against 11.13 ± 2.40 MPa for the E&R (14); 573.65 ± 71.66 N for the SAC against 457.46 ±115.35 N for the SE (22); 13.52 MPa for the SAC against 7.41 MPa for the SE and 11.15 for the E&R (6).

  Finally, 5 articles reported similar PBS values between SAC and SE or E&R (9,13,25–27).

  Thus Almulhim et al. (25) and Dimitrouli et al. (27) conclude that SAC is a viable alternative to conventional luting agents thanks to their simplicity of use.
- When comparing E&R and SE adhesives, 1 study (28) reported higher PBS values for E&R: 18.2 ± 6.8 MPa against 17.9 ± 7.7 MPa ; 1 study (29) found better PBS values when using SE: 24.33MPa against 18.61 MPa; and 1 other study (30) found similar PBS values between E&R and SE adhesives.
- In all the studies PBS values were highest in the coronal third, followed by the middle third and finally the apical third. SAC showed higher PBS values in the apical third : 16.19 ± 7.92MPa for the SAC against 7.27 ± 3.31 for E&R (10); 14.72 ± 3.03 MPa for the SAC against 5.85 ± 1.53 MPa for the E&R (8); 9.9 MPa for the SAC against 7.0 MPa for the E&R (17).

5 DISCUSSION

5.1 Importance of cement

When restoring endodontically treated teeth using glass fiber posts debonding from dentin is still one of the main complication and reason for failure. (4) This failure is influenced by different factors and characteristics : the dentin is dehydrated, the previous preparation of the canal leads to the presence of dentin particles and debris of gutta-percha and cement (2), the dentinal tubules have different orientation (16), high C-factor, lower third of the canal offers a limited access and visibility (1). The choice of adhesive and cement is therefore crucial in the realization of this type of restoration.

For luting glass fiber posts to root dentin, resin-base cements are mainly used.(31) They increase post retention, increase fracture resistance and prevent coronal microleakage. (32) Glass fiber posts are mostly luted using dual-cured resin cements which are activated both by light and chemically. (9) However, as described above, the deeper parts of the channel represent a difficulty for light activation because there is a significant reduction of light transmission. (18) Morphological variations can also accentuate this, which leads to a bond strength reduction and can eventually result to debonding or fractures. Dual-cured resin cements are commonly used with the previous addition of a E&R or SE adhesive, employed for etching enamel and dentin. (9) These adhesives help to overcome the polymerization defects mentioned above. (18) However, E&R and to a lesser extent, SE represent a multiplication of steps, they are more technique sensitive and they can also lead to missteps on the part of the operator, all this may compromise bonding effectiveness. (8) This explains the interest and popularity of SACs in these past years.

SACs combine all components into a single product and reduce the amount of time spent and potential errors. No conditioning or bonding are needed and the application of SARCs can be achieved in a single step. (8) They contain acid monomers in their structure for dissolving the smear layer, allowing cement to infiltrate dentinal tubules. Chemical adhesion is also promoted through the interaction with hydroxyapatite calcium. Another characteristic of SACs compared to conventional cements is the tolerance to humidity, which makes them less technique sensitive. (33)

5.2 Influence of adhesives

5.2.1 Universal Adhesives

Regarding UA, of the 27 articles selected, 3 studies have studied and demonstrated their effectiveness. (1,4,14) This can be explained by the lower acid composition of UA compared to conventional phosphoric acids. This avoids demineralizing the entire mineral phase of the enamel and allows to create micro-retentive porosities. (4) In addition, two of the studies showed a higher efficiency of UA in SE mode compared to E&R mode mainly for the apical third. It can be explained by the difficulty of access to this part of the root canal, which can prevent the etchant from reaching this part. This difficulty also results in the presence of water or residual solvent and may prevent the etchant from being completely removed. (4,14)

It can be noted, as shown in the study by Shafiei et al. (2018) that the irrigant used has an influence on the performance of UA depending of the mode used. SE mode showed better performance with EDTA and E&R performed better when using NaOCl. NaOCl has a low efficacy to remove the smear layer which can explain this result. On the contrary, EDTA allows a greater stability and residual minerals which offers a favorable bonding substrate. (1)

It can be concluded that universal adhesives, used in appropriate conditions, represent an interesting alternative due to their versatility and ease of use, especially in SE mode.

5.2.2 Etch&Rinse and Self-Etch

Regarding the studies comparing E&R and SE adhesives with each other, the results are mixed. Some studies report better results for E&R adhesives, others have shown that SE has better results. But in each case the authors conclude that the results can be considered similar for both types. (28–30)

In view of these results it may be interesting to consider the advantages of SE adhesives in comparison to E&R. First of all, since there is no etching step, the use of this type of adhesive is a time saver for the operator and the patient.(28) As stated above and confirmed by other studies, the SE adhesives show better results in comparison to E&R in the apical segment because they avoid unremoved etchant or the presence of water due to rinsing, which leads to moisture control detrimental to optimal adhesion. (14,29) Another property of SE is its lower acid composition compared to the phosphoric acid used with E&R adhesives. As with UAs, this characteristic allows them to achieve better adhesion results.(4)

One argument against SE adhesives in several studies is their inability to penetrate thick smear layers. Yet, no evidence to support this was found in the articles reviewed here. In addition, the use of a suitable irrigant (EDTA) during the canal preparation would override this limitation if necessary. (1,29,30)

Thus, SE adhesives can be considered as a better option compared to E&R adhesives as they are less technique sensitive, less time consuming while presenting similar or even superior results.

5.3 Influence of cements

Of the 27 articles selected, 21 studied and compared different types of cements, in particular comparing conventionally used dual cured resin cements and self-adhesive cements. In the majority of these studies (15), **self-adhesive cements showed PBS** results superior or at least equal to dual cured resin cements. (6,8,23–27,9–14,21,22)

This is explained firstly by the adhesion between the SAC and the dentin, which is achieved by the interaction between the acidic monomers of the cement and the calcium ions of the hydroxyapatite. In the use of SAC this interaction is more important in obtaining an optimal bond strength than the ability to hybridize the dentin. (6,8,10,11,14,21,22,24) In addition, this reaction allows the cement to acquire hydrophobic properties, a feature of interest here compared to conventional DCCs that are sensitive to moisture, a parameter that is difficult to control and can be the cause of failure.(10,11,21)

It is also described by some authors that SACs yield low shrinkage, which is attributed to their viscoelastic properties. This property allows the SAC to have better contact with the root canal walls and gives them a greater frictional resistance. According to Amaral et al. (2011) this feature is particularly interesting in the case of a high C-factor. (23,24)

Even though the apical region of the canal shows the lowest bond strength values regardless of the luting system used several studies have shown better results in the apical part for SACs, especially in comparison to DCC using E&R adhesives.(9,10,17) This difference can be explained by the difficulty of reaching this part for the etchant and the adhesive or the presence of residual remains of etchant or water among others. According to Kahnamouei et al. (2012) this is mainly due to the facts that SACs are less sensitive to dentin depth and tubular density than other cements.(10)

Despite the arguments in favor of SAC described here, some studies have shown lower PBS results for SAC when compared to conventional DCC.(15–20) This is mainly due to the low capacity of SAC to hybridize dentin, what is currently considered the main limitation and concern regarding these materials. To dissolve the smear layer, methacrylated phosphoric esters are present in the composition of SACs, replacing the use of phosphoric acid. These methacrylated phosphoric esters would however be less effective, especially in the presence of thick smear layers and this may result in gaps between the surfaces, reducing the adhesion.(8,17,19) To address this issue, In the study by Durski et al. (2016) the authors propose adding an etching conditioning step with 37% phosphoric acid prior to SAC application. They obtained better bonding results due to better hybridization of the dentin.(8)

Another method to improve adhesion when using SACs demonstrated by several authors is the application of an adhesive prior to the cement. Oskoee et al. (2016) thus demonstrated the positive effect on bond strength using a universal adhesive in SE mode with a SAC. This is in accordance with the results of Juloski et al. (2013), here using a SE adhesive.(12,14)

In their studies Durski et al (2016) compared the use of a microbrush or an elongation tip for the application of SAC. It is concluded that the elongation tip allows to obtain better results, the application of the cement along the root surface canal being more homogeneous. Moreover, the cement is mechanically mixed in a capsule, which avoids the presence of air bubbles.

It should also be noted that some dual-cured cements used with a self-etch adhesive have shown results superior or equal to SACs. This is for instance the case for ParaCore used with Parabond, an adhesive SE. One of the reasons for this is that ParaBond is chemically cured, which makes it effective in places where light cannot penetrate, an interesting property when cementing post. In addition, the shape of the ParaCore syringe allows for ideal mixing and insertion of the material. (13)

Another notable DCC is the RelyX Ultimate. It contains 10-methacryloyloxydecyl dihydrogen phosphate monomers in its composition. These MDPs when used in combination with an SE allow the creation of chemical bonds between the phosphate groups and the residual hydroxyapatite crystals of the dentin. This allows greater stability in water and reduces the degradation of the hybrid layer through time.(9)

The DCC Gradia Core used with its SE adhesive also showed similar results compared to a SAC. However, it is interesting to note that the same SAC used with the Gradia Core SE adhesive showed better results than the DCC Gradia Core. (12)

5.4 Limitations of the study

The first limitation of this work is that all the selected studies are *in vitro* studies. Even though the *in vivo* conditions are simulated with the greatest care, it is important to consider the results carefully because of the limitations inherent to the laboratory conditions of this kind of studies. Moreover, out of the 27 selected studies, 7 were performed on bovine teeth, which represents 25% of the selection.

It should also be considered that between each study the protocols and parameters are different, which can make it difficult to compare results between studies. This is one of the reasons why we chose to focus on the results of the Push Out Bond test, which makes the comparison between the studies a little more coherent and relevant.

6 CONCLUSION

Based on the above results, it can be concluded that there is a difference between the different types of cements and adhesives when using glass fiber posts. The choice of cements and adhesives is therefore an important step in the success of this type of procedure.

The main conclusions of the selected studies can be drawn as follows:

- SACs allows to obtain equal or better results than conventional cements due to their different chemical and mechanical properties, as shown by the push out bond strength results, in addition to their simplicity of use and the time saving that their use represents.
- UA represent a good alternative, especially in SE mode, to conventional adhesives due to their ease of use, versatility and performance similar or better than E&R or SE adhesives.
- When comparing SE and E&R, the use of SE adhesives may be preferable as they are less technique sensitive and easier to use with similar results of push-out bond strengh.
- When using SE adhesives it is important to note the influence of the irrigant used. Thus EDTA allows to obtain better results with SE.
- The performance of SACs can be improved with the use of SE adhesives or UA in SE mode, by adding an etching step or by using an elongation tip
- The apical third of the canal represents the zone where adhesion is the lowest, and is therefore a critical zone for the success of this type of procedure

It can be noted that there is the predominance of one SAC, RelyX Unicem, in many of the studies. Therefore, it would be necessary to carry out more studies or investigations on other SACs to be able to extrapolate the results observed in this work to SACs in general and not just one specific product. These studies may include the interest of adding an etching step when using SAC.

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